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Distributed system of protection and diagnostics of support structural elements of high-voltage power lines

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Abstract

A distributed system of protection and diagnostics of support structural elements of high-voltage power lines (HVPL) on 500 kV voltage was developed at Karaganda State technical university:
- current monitoring of leakage currents of bunches of suspension insulators;
- detection ice-rime depositions;
- cathode protection of underground elements of support constructions;
- information transfer from the sensors placed on supports on the control office on telemetric channels;
- creation of the passport of each support on SCADA – system basis.

The system contains set of local subsystems constructively placed on the HVPL support, telemetry subsystem providing processing and information transfer from the sensors placed on support, a subsystem of processing and information storage on the control offices of different level. Power supply of local subsystems is provided from the directed energy of electromagnetic fields. The local subsystem consists of three identical, hybrid sensors of a leakage current of suspension insulators, Ice-rime depositions detection is carried out by the indirect methods based on the current monitoring of support reaction to wind and ice loads, and also temperatures and air humidity. Information from sensors allows to control the integral values of a leakage current of the industrial frequency and surface currents of the partial discharges proceeding through insulators bunches, and also to define the time point which is optimum for ice-rime depositions. Radio modem, cellular, and also satellite communication with an automatic channels choice of communication in the conditions of the powerful electromagnetic fields having significant effect on an opportunity and transmission quality of information is used for telemetric information transmission to the control office The passport of each controlled section support of HVPL which has the information archive on technical elements condition of HVPL construction support, trends of leakage currents, about the current alert conditions with localization of the place, time and a type of an alert condition was created in the control office.

Keywords: High-voltage power lines, system of protection and diagnostics, supports, leakage currents of high-voltage insulators, ice-rime depositions, cathode protection, telemetry, alternative channels, support passport

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1. Introduction

In the CIS countries power transmission on long distances is carried out by air high-voltage power lines (HVPL) [1].

Any accident, on HVPL of 110-500 kV, connected with arc overlapping suspended insulators, break of current carrying wires, supports falling, leads to interruptions of power supply of the whole regions.

Reliability of work and size of active losses of the HVPL electric power extremely depends on a condition of suspended insulators. Now remote contactless ways of preventive control of insulators with use of electron-optical defectoscopes [2-7] are used. Realization of these methods requires direct visual contact with supports therefore diagnostics can be made only selectively and with a big frequency. Therefore they are inapplicable for the supports established in boggy places, in mountainous and rocky areas. Big errors arise because of a corona effect on suspended insulators and influences of solar illumination at their use.

Considerable influence on reliability of power transmission on air-lines in the conditions of Kazakhstan and Russia is rendered by extreme climatic factors, including the ice-rime depositionions leading to severe accidents (to 30% of emergency HVPL shutdowns) [8-10].

There are various ways of measurement control of the ice load of the current carrying elements of overhead power transmission lines [10-13] based on the analysis of various physical effects accompanying ice depositions. However these ways weren't widely adopted because of insufficient sensitivity, big mistakes, and also high complexity and insufficient reliability of ice detection on HVPL.

Essential decrease in a resource of support is caused by processes of electrochemical corrosion of the elements of fastening located underground, and protection systems against these processes on HVPL are absent.

Lack of the existing control methods and HVPL protection is their fragmentariness, they are not compatible among themselves and cannot be applied to continuous complex monitoring of a condition of each of the HVPL supports.

At the Karaganda State technical university the distributed system of protection and diagnostics of structural elements of the HVPL supports was developed [14-19]:

- current control of currents of bunches leakage of the suspended insulators;
- identification ice-rime depositions;
- cathodic protection of underground elements of the support constructions;
- information transfer from the sensors placed on support on control office on telemetric channels;
- creation of each support passport on the basis of SCADA – system.

Distinctive feature of system is its complexity that has allowed to solve within one project problems of protection and diagnostics of construction elements of HVPL in various parameters on the basis of the integrated telemetry and uniform approaches to design. High reliability of the telemetry channel is provided with use of various channels of the local system, situated on HVPL support and dispatch center with automated variant choice (radio modem, cellular, and also satellite communication) according to authenticity criterion of information.

2. Description and characteristics of the protection system and diagnostics

The protection system and diagnostics represents set of the local subsystems which are structurally placed on the HVPL support, the telemetry subsystem providing processing and information transfer from the sensors placed on support, a subsystem of processing and storage information on control office of various level. The generalized functional chart of system is represented in the figure 1.

A hybrid sensor which feature is monitoring of integral values of a leakage current of industrial frequency and current of the partial discharges of suspension insulators, which construction considers features of fixing in the grounded part of the suspension isolation center was developed for monitoring the value of leakage currents of the suspension insulator [20]. Power supply is

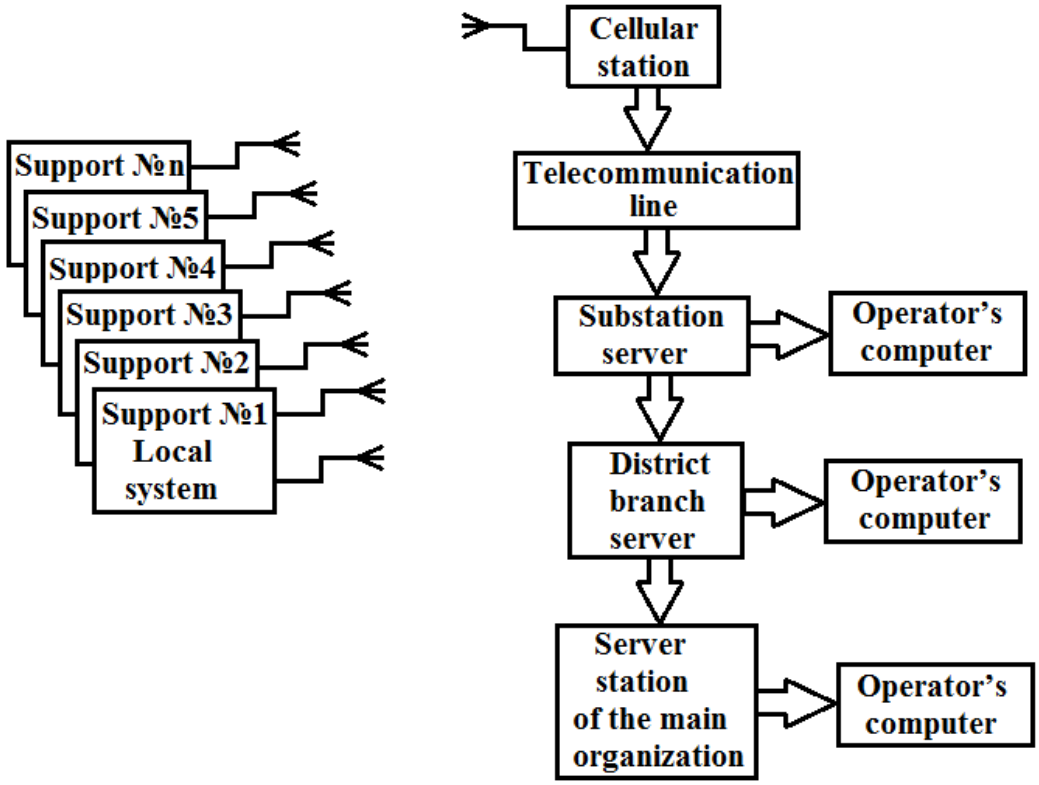

Figure 1. Functional system diagram

implemented on wires, and information from its outputs is transmitted through a radio modem that increases reliability of system in the hybrid current sensor. A structural diagram of the current sensor is provided in a figure 2.

The hybrid current sensor controls two parameters of leakage currents of suspension insulators HVPL [21]:

- an average value of the background current module of the industrial frequency;
- an average value of the surface current module of the partial discharges.

The hybrid sensor consists from:

- a current sensor of the partial discharges – CSPD;
- a sensor of the background current of industrial frequency – SBCIF;
- a current sensor controller – CSC;
- a radio modem – RM;
- a power supply unit – PSU.

A controller of the current sensor performs the following functions:

- constant inquiry of information analog outputs of CSPD and SBCIF, and also processing of the test signal with 1B tension, created by power supply unit and the discrete signals of synchronization in the cyclic mode;
- averaging of multiply repeated information signals from CSPD and SBCIF output;
- computation of admissible value of a zone of an output signals dispersion from CSPD and SBCIF sensors;
- synchronization of the controller current time of the control local system (CLS) and CSC in the cyclic mode.

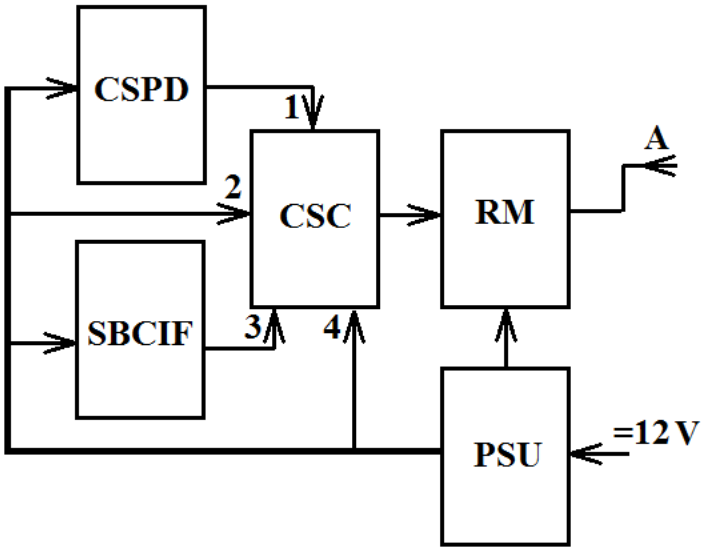

Figure 2. A structural diagram of the sensor of leakage currents

The strucural diagram of the local subsystem performing functions of collection and preprocessing with the subsequent transmission of the telemetric information to the control office is showed in a figure 3.

The local subsystem consists of three identical, hybrid sensors of current and an electronic unit. Sensors of leakage currents on phases (SCA, SCB, SCC) transfer with the given periodicity on a radio channel the current information about value of the leakage current to the electronic unit. A time interval of the inquiry of current sensors changes in value of a leakage current. The maximum time of an interval of the inquiry corresponds to the minimum value of the leakage current. The interval of time is reduced with increase in a leakage current. Control of an interval time inquiry of leak current sensors is executed of the controller of local system. The Electronic Unit (EU) includes the hybrid sensor of temperature and humidity (STH), and also a three-coordinate gyroscope (TCG), a controller of conversion of output signals of TCG is CCOS, the

controller of local system (CLS), two radio modems — cellular (GPSMLS) and a radio communication (RMLS), the stabilized power supply unit (SPSU).

Power supply of the local subsystems is situated on supports provided from the directed energy of electromagnetic fields.

Detection ice-rime deposits is carried out by the indirect methods based on monitoring reaction of a support to wind and ice loads. The current control of the support acceleration in three planes, and also temperature and air humidity are for this purpose.

When comparing signals of the support acceleration in three planes and a support deviation corner on an axis HVPL, and also temperature signals and air humidity, the probability of icing process origin on current carrying wires is established with the preset values.

Radio modem, cellular, and also satellite communication with an automatic choice of channels of communication in the conditions of the powerful electromagnetic fields directed in the HVPL elements when transporting the electric power is used for telemetric information transmission to the control office.

Information transfer from support on the server is executed on cellular communication in the presence of stable cellular communication. At the same time the considerable sections of HVPL-

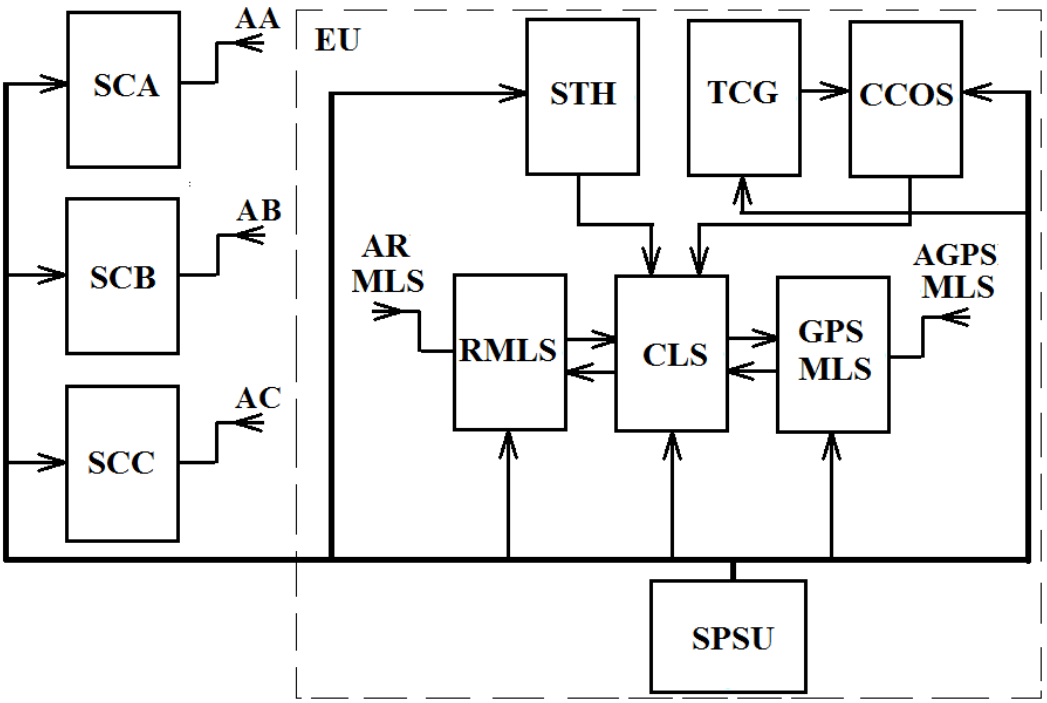

Figure 3. Structural diagram of the local subsystem

500, because of remoteness of lines from settlements, and also because of a land features, are not enveloped by cellular communication.

In this regard technical capability of information transfer on a chain from a support to a support is provided until there is an opportunity to transfer information by funds of cellular communication to the control office.

In that case if information transfer, for any reasons does not arise, CSC continues in the cyclic mode with the given interval of time to execute inquiry of CSPD and SBCIF information channels and to make computation of average values, and also the ranges of dispersion zones of output signals for each information channel, all information taking into account the current time is saved in the controller non-volatile memory of local system.

The passport of each support of a HVPL controlled section which supports archive of information on technical condition of construction elements of HVPL support, trends of leakage about the current alert conditions with localization of the place, time are created in the control office.

Predicting mathematical development models of alert conditions, and also controlled elements aging of HVPL support construction were created on the basis of the analysis of the current values of leakage, technologic forecasting of frosting HVPL current elements is provided. Diagnostics of the equipment status of local systems and sensors is performed, recommendations, on changeover of elements of HVPL support are created.

Now the experimental samples of leakage currents sensors are developed and tested. Units of the cathode protection of underground support elements are worked out and tried. The experimental samples of processing units and information transfer from support are created and tested. Different options of power supply units of system placed on support are fulfilled. Technical solutions on monitoring of frosting wires are fulfilled.

A continuous monitoring of the units currents of the cathode protection placed on operating high-voltage substation within 10 months, transformed in the industrial controller and transmitted through mobile networks was provided. Processing of the acquired information was carried out in laboratory of university in real time.

Quality of the accepted telemetry is quite satisfactory. Efficiency of the cathode protection of underground elements of construction support is confirmed. The minimum values of the cathodes currents are defined, and also developed constructions of cathodes are approved.

3. Conclusion

At the Karaganda State technical university the distributed system of protection and diagnostics of structural elements of HVPL-500 supports was developed:

• current monitoring of leakage currents of bunches of suspension insulators;

• detection ice-rime depositions;

• cathode protection of underground elements of support constructions;

• information transfer from the sensors placed on supports on the control office on telemetric channels;

• creation of the passport of each support on SCADA – system basis.

The system represents set of local subsystems constructively placed on the HVPL supports, a telemetry subsystem providing processing and information transfer from the sensors placed on supports, a subsystem of processing and information storage on control office of different level.

Radio modem, cellular, and also satellite communication with an automatic choice of channels of communication in the conditions of the powerful electromagnetic fields directed in the HVPL elements when transporting the electric power are used for telemetric information transmission to the control office.

Distinctive feature of system is complexity that allowed to solve within one project problems of protection and elements diagnostics of construction of HVPL in different parameters on the basis of the integrated telemetry and uniform design approaches.

The main technical solutions created in development process of system can be applied during creation of software and hardware complexes to other applications where support of the continuous monitoring of the distributed technical systems is necessary.

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